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**SYSTEM, DEVICE, AND METHOD FOR PROVIDING NETWORK  
ACCESS IN A COMMUNICATION SYSTEM**

5                   **CROSS-REFERENCE TO RELATED APPLICATION(S)**

The present application may be related to the following commonly owned United States patent application, which is hereby incorporated herein by reference in its entirety:

10           United States Patent Application No. XX/XXX,XXX entitled SYSTEM, DEVICE, AND METHOD FOR MAINTAINING COMMUNICATION SESSIONS IN A COMMUNICATION SYSTEM, filed on even date herewith in the name of Franco Travostino.

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**FIELD OF THE INVENTION**

The present invention relates generally to communication systems, and more particularly to providing network access in a communication system.

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**BACKGROUND OF THE INVENTION**

In a typical wireless communication system, wireless terminal  
25   equipment (TE) devices access a host computer through various access point (AP) devices. The AP devices communicate with the TE devices using a wireless communication protocol, and communicate with the host computer using some other protocol, such as a local area network (LAN) protocol. Each communication protocol is typically composed of various protocol layers in  
30   what is often referred to as a protocol stack. The protocol layers are typically implemented in software, and require certain processing resources as well as certain memory resources (e.g., for the storage of state information and data). The AP devices typically support and implement the full wireless communication protocol stack, and therefore the AP devices are typically  
35   complex devices that require substantial processing and memory resources.

One wireless communication protocol is commonly known as Bluetooth. Bluetooth defines a wireless (RF) protocol layer as well as various combinations of higher protocol layers (referred to in Bluetooth as profiles) for using Bluetooth in various applications. Bluetooth is described in a Bluetooth core specification entitled Specification of the Bluetooth System Core, Volume 1.0 B, dated December 1, 1999, which is hereby incorporated herein by reference in its entirety. Bluetooth profiles are described in a Bluetooth profiles specification entitled Specification of the Bluetooth System Profiles, Volume 1.0 B, dated December 1, 1999, which is hereby incorporated herein by reference in its entirety. For convenience, the Bluetooth core specification and the Bluetooth profiles specification are referred to hereinafter collectively as the Bluetooth specification.

FIG. 1 shows a representation of a conventional wireless communication system 100 in accordance with an implementation of Bluetooth. The TE device 102 accesses the host computer 108 via the AP device 106, using a wireless communication protocol to communicate with the AP device 106 over a wireless medium 104 (e.g., RF through air, infrared through air).

The AP device 106 typically implements the full wireless communication protocol stack. Therefore, the AP device 106 is typically a complex device having substantial processing and memory resources.

FIG. 2 illustrates the various protocol stacks that are supported and implemented by the TE device 102, the AP device 106, and the host computer 108 within the conventional wireless communication system 100 in accordance with a LAN Access Profile of the Bluetooth specification.

The TE device 102 includes, among other things, baseband transceiver logic 202 with associated host controller interface (HCI) firmware 204 for sending and receiving protocol messages over the wireless medium 104, HCI

driver logic 206, logical link control and adaptation protocol (L2CAP) logic 208 for providing connection-oriented or connectionless layer 2 services, link manager protocol (LMP) logic 210, service discovery protocol (SDP) logic 212, RF communication logic 214 for emulating multiple RS-232 connections over L2CAP, Point-to-Point Protocol (PPP) logic 216, Internet Protocol (IP) logic 218, TCP/UDP logic 220, and a number of applications 222.

The AP device 106 includes, among other things, a first protocol stack for communicating with the TE device 102 and a second protocol stack for communicating with the host computer 108. The first protocol stack includes, among other things, baseband transceiver logic 224 with associated HCI firmware 226 for sending and receiving protocol messages over the wireless medium 104, HCI driver logic 228, L2CAP logic 230, LMP logic 232, SDP logic 234, RF logic 236, PPP logic 238, IP logic 240, and Dynamic Host Configuration Protocol (DHCP) logic 242. The second protocol stack includes, among other things, LAN logic 244, IP logic 240, Proxy ARP (Address Resolution Protocol) logic 246 for resolving addresses, and AAA (authentication, authorization, and accounting) logic 248.

The host computer 108 includes, among other things, LAN logic 250, IP logic 252, TCP/UDP logic 254, and a number of applications 256.

### SUMMARY OF THE INVENTION

In an embodiment of the present invention, the AP devices work in combination with a back end (BE) device to provide wireless access for the TE devices. Specifically, the wireless communication protocol stack is divided between the AP devices and the BE device, with the AP devices supporting and implementing a first protocol layer of the wireless communication protocol stack (typically the lowest protocol layer of the wireless communication protocol stack), and the BE device supporting and implementing a second protocol layer of the wireless communication protocol

stack (typically the upper layers of the wireless communication protocol stack). Each AP device is coupled to the BE device over a communication network, such as an Ethernet LAN, and establishes a communication connection to the BE device. Protocol messages received by the AP devices from the TE devices are forwarded by the AP devices to the BE device over the pre-established communication connections, and protocol messages received by the AP devices from the BE device over the pre-established communication connections are forwarded by the AP devices to the TE devices. The AP devices are therefore "thin" AP (TAP) devices that support and implement only a small subset of the wireless communication protocol stack and therefore require minimal processing and memory resources. This allows the TAP devices to be small, simple, inexpensive devices that can be placed unobtrusively and ubiquitously within a networking environment. The BE device includes sufficient processing and memory resources for supporting many TE devices accessing the network through multiple TAP devices, and communicates with the host computer on behalf of the TE devices. It should be noted that this division of the wireless communication protocol stack between the TAP devices and the BE device is transparent to the TE devices and to the host computer, which require no changes to operate in such a wireless communication system.

In one embodiment of the invention, the protocol layers of a wireless communication protocol are divided between an access point device and a back end device such that the access point device implements a lower protocol layer of the wireless communication protocol and the back end device implements upper protocol layers of the wireless communication protocol.

The access point device receives upper protocol layer information from a terminal equipment device via the lower protocol layer and forwards the upper protocol layer information to the back end device over a pre-established communication connection.

The back end device receives the upper protocol layer information from the access point device over the pre-established communication connection and processes the upper protocol layer information.

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The back end device forwards upper protocol layer information to the access point device over the pre-established communication connection.

10 The access point device receives the upper protocol layer information from the back end device over the pre-established communication connection and forwards the upper protocol layer information to the terminal equipment device using the lower protocol layer.

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#### **BRIEF DESCRIPTION OF THE DRAWINGS**

In the accompanying drawings:

FIG. 1 is a system diagram showing an example of a conventional wireless communication system;

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FIG. 2 is a block diagram showing sample protocols stacks of various devices in a conventional wireless communication system;

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FIG. 3 is a system diagram showing an example of a wireless communication system in which an access point device implements a lower protocol layer of a wireless communication protocol and a back end device implements upper protocol layers of the wireless communication protocol in accordance with an embodiment of the present invention;

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FIG. 4 is a block diagram showing sample protocol stacks of the access point device and the back end device in accordance with an embodiment of the present invention;

FIG. 5 shows a representation of a wireless protocol message for communication between a terminal equipment device and the access point device in accordance with an embodiment of the present invention;

FIG. 6 shows a representation of a PPP/PPPoE protocol message for communication between the access point device and the back end device in accordance with an embodiment of the present invention;

FIG. 7 is a logic flow diagram showing sample access point device logic for processing a wireless protocol message received from the terminal equipment device in accordance with an embodiment of the present invention;

FIG. 8 is a logic flow diagram showing sample back end device logic for processing a PPP/PPPoE protocol message received from the access point device in accordance with an embodiment of the present invention;

FIG. 9 is a logic flow diagram showing sample back end device logic for sending upper protocol layer information to the access point device in accordance with an embodiment of the present invention; and

FIG. 10 is a logic flow diagram showing sample access point device logic for processing a PPP/PPPoE protocol message received from the back end device in accordance with an embodiment of the present invention.

#### **DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT**

In an embodiment of the present invention, the AP devices work in combination with a back end (BE) device to provide wireless access for the TE devices. Specifically, the wireless communication protocol stack is divided between the AP devices and the BE device, with the AP devices supporting and implementing a first protocol layer of the wireless communication protocol stack (typically the lowest protocol layer of the wireless communication protocol stack), and the BE device supporting and implementing a second protocol layer of the wireless communication protocol stack (typically the upper layers of the wireless communication protocol stack). Each AP device is coupled to the BE device over a communication network, such as an Ethernet LAN, and establishes a communication connection to the BE device. Protocol messages received by the AP devices from the TE devices are forwarded by the AP devices to the BE device over

the pre-established communication connections, and protocol messages received by the AP devices from the BE device over the pre-established communication connections are forwarded by the AP devices to the TE devices. The AP devices are therefore "thin" AP (TAP) devices that support  
5 and implement only a small subset of the wireless communication protocol stack and therefore require minimal processing and memory resources. This allows the TAP devices to be small, simple, inexpensive devices that can be placed unobtrusively and ubiquitously within a networking environment. The BE device includes sufficient processing and memory resources for  
10 supporting many TE devices accessing the network through multiple TAP devices, and communicates with the host computer on behalf of the TE devices. It should be noted that this division of the wireless communication protocol stack between the TAP devices and the BE device is transparent to the TE devices and to the host computer, which require no changes to operate  
15 in such a wireless communication system.

Bluetooth is one wireless communication system that can benefit from such division of the wireless communication protocol stack between the AP devices and the BE device. Bluetooth is a wireless access protocol that uses  
20 multiple AP devices spread throughout a networking environment to provide wireless access for portable TE devices. The effectiveness of the Bluetooth communication system is dependent to a large degree on the number and placement of the AP devices within the networking environment. Increased performance can be realized by increasing the number of AP devices. Because  
25 the AP devices are typically complex devices having substantial processing and memory resources, increasing the number of AP devices substantially increases the overall cost of the communication system. However, by using TAP devices that are small, simple, and inexpensive, it is possible to increase the number of AP devices without unduly increasing the overall cost of the  
30 communication system. For convenience, various embodiments of the invention are described herein in the context of a Bluetooth wireless communication system.



In an embodiment of the present invention, the wireless communication protocol stack (e.g., Bluetooth) is divided between TAP devices and a BE device. Each TAP device establishes a communication connection to the BE device. In a typical embodiment, the TAP devices communicate with the BE device over an Ethernet LAN, and the pre-established communication connections are Point-to-Point Protocol (PPP) connections that are established using a PPP-over-Ethernet (PPPoE) control protocol (referred to hereinafter as PPP/PPPoE communication connections). Protocol messages received by the TAP devices from the TE devices are forwarded by the TAP devices to the BE device over the pre-determined PPP/PPPoE communication connections, and protocol messages received by the TAP devices from the BE device over the pre-determined PPP/PPPoE communication connections are forwarded by the TAP devices to the TE devices.

FIG. 3 shows a representation of a wireless communication system 300 in which the Bluetooth wireless communication protocol stack is divided between TAP devices and a BE device. The TE device 102 accesses the host computer 108 via the TAP device 306 using the Bluetooth wireless communication protocol. The TAP device 306 establishes a PPP/PPPoE communication connection to the BE device 307. Protocol messages received by the TAP device 306 from the TE device 102 are forwarded by the TAP device 306 to the BE device 307 over the pre-determined PPP/PPPoE communication connection, and protocol messages received by the TAP device 306 from the BE device 307 over the pre-determined PPP/PPPoE communication connection are forwarded by the TAP device 306 to the TE device 102. The BE device 307 includes sufficient processing and memory resources for supporting the TE device 102 and may other TE devices (not shown) accessing the network through the TAP device 306 and other TAP devices (not shown), and communicates with the host computer 108 on behalf of the TE device 102.

FIG. 4 illustrates the various protocol stacks that are supported and implemented by the TE device 102, the TAP device 306, the BE device 307, and the host computer 108 within the wireless communication system 300 in accordance with a LAN Access Profile of the Bluetooth specification. It should be noted that the protocol stacks in both the TE device 102 and the host computer 108 are the same in both the conventional communication system 100, as shown in FIG. 2, and the communication system 300, as shown in FIG. 4.

The TE device 102 includes, among other things, baseband transceiver logic 202 with associated HCI firmware 204 for sending and receiving protocol messages over the wireless medium 104, HCI driver logic 206, L2CAP logic 208, LMP logic 210, SDP logic 212, RF logic 214, PPP logic 216, IP logic 218, TCP/UDP logic 220, and a number of applications 222.

The TAP device 306 includes, among other things, a first protocol stack for communicating with the TE device 102 and a second protocol stack for communicating with the BE device 307. The first protocol stack implements the lower protocol layer of the wireless communication protocol, and includes, among other things, baseband transceiver logic 224 with associated HCI firmware 226 for sending and receiving protocol messages over the wireless medium 104. The second protocol stack includes, among other things, LAN logic 402, PPPoE control protocol logic 404 for establishing a PPP/PPPoE communication connection to the BE device 307 over the LAN, and PPP logic 406 for transferring protocol messages between the TE device 102 and the BE device 307.

The BE device 307 includes, among other things, a first protocol stack for communicating with the TAP device 306 and a second protocol stack for communicating with the host computer 108. The first protocol stack implements the PPP/PPPoE protocols for communicating with the TAP

device 306 and also implements the upper protocol layers of the wireless communication protocol, and includes, among other things, LAN logic 244, PPPoE control protocol logic 410, PPP logic 412, HCI driver logic 228, L2CAP logic 230, LMP logic 232, SDP logic 234, RF logic 236, PPP logic 238, IP logic 240, and DHCP logic 242. The second protocol stack includes LAN logic 244, proxy ARP logic 246, and AAA logic 248.

The host computer 108 includes, among other things, LAN logic 250, IP logic 252, TCP/UDP logic 254, and a number of applications 256.

It should be noted that the TAP device 306 includes very little logic, and the logic that is included in the TAP device 306 is not required to maintain substantial state information. Essentially, the TAP device 306 is only responsible for managing radio frequencies, amplifying signal over noise, performing retransmissions, establishing and maintaining the PPP/PPPoE connection to the BE device, and transferring protocol messages between the TE devices and the BE device. State information required by the TAP device 306 includes such things as PPP/PPPoE session identifier and settings (e.g., MTU), baseband retransmission state, and ACL/SCO mappings and channel properties for the LMP. Certain state information, such as the PPP/PPPoE session identifier and settings and the ACL/SCO mappings and channel properties are maintained by the BE device 307, and can therefore be recovered by the TAP device 306 from the BE device 307 rather than maintained by the TAP device 306.

On the other hand, the BE device 307 includes substantial logic and maintains substantial state information. The BE device 307 provides or may provide various state-based services. DHCP services typically include such things as reserving/allocating IP addresses for the TE devices and optimizing for use/re-use of the IP address space. AAA services may include such things as implementing an AAA client, implementing a remote AAA server, or implementing whole server functionality (e.g., for sharing policy information

with other BE devices via a distributed file system). Proxy ARP services typically include returning TE device MAC addresses in response to queries received from the host computer. SDP services typically include such things as maintaining a database of services (such as Bluetooth services) and

5 processing queries to the database (e.g., keyed on the TAP device from which the query is received). RF services typically include tracking existing sessions over the RS-232 emulation. PPP services typically include maintaining session identifier and settings (e.g., MTU) for PPP connections between the TE devices and the BE device. LMP services typically include such things as a

10 link key, encryption status, encryption key, encryption key size, QoS classes, and hold/sniff/park toggles. L2CAP services typically include such things as packet re-assembly, upper-protocol and lower-protocol state machines, connection information for connection-oriented channels, and MTU and QoS classes. PPP/PPPoE services typically include maintaining session identifier and settings for the PPP/PPPoE connections to the TAP devices. Additional

15 services may include such things as network address translation (NAT), firewall functionality, configuration/management services (e.g., via SNMP), and BE device pooling (i.e., maintaining multiple BE devices for aggregation and load balancing).

20 In order for communications to occur between the TE device 102 and the host computer 108, wireless layer 1 protocol exchanges occur between the TE device 102 and the TAP device 306, while wireless layer 2 protocol exchanges occur between the TE device 102 and the BE device 307. Thus, the

25 TE device 102 and the TAP device 306 are peer devices at the baseband layer, while the TE device 102 and the BE device 307 are peer devices at the higher wireless communication protocol layers, such as L2CAP, RF, SDP, and PPP layers.

30 In order to transfer protocol messages between the TE device 102 and the BE device 307, protocol layers within the TAP device 306 interoperate with peer protocol layers in the TE device 102 and the BE device 307.

Specifically, the baseband logic and HCI firmware in the TAP device 306 interoperate with peer baseband logic and HCI firmware in the TE device 102. Also, the LAN logic, PPPoE control protocol logic, and PPP logic in the TAP device 306 interoperate with peer LAN logic, PPPoE control protocol logic, and PPP logic in the BE device 307.

More specifically, the TE device 102 communicates with the host computer 108 by forming a wireless protocol message and transmitting the wireless protocol message to the TAP device 306. FIG. 5 shows a representation of a wireless protocol message 500 sent by the TE device 102 to the TAP device 306. The wireless protocol message 500 includes an upper layer payload encapsulated in a wireless layer 2 packet. The TE device 102 transmits the wireless protocol message 500 to the TAP device 306 using the wireless layer 1 protocol.

When the TAP device 306 receives the wireless protocol message 500 from the TE device 102, the TAP device 306 forms a PPP/PPPoE protocol message and forwards the PPP/PPPoE protocol message over a pre-established PPP/PPPoE communication connection to the BE device 307. Specifically, the TAP device 306 extracts the wireless layer 2 packet (including the upper layer payload) from the wireless protocol message 500, and encapsulates the wireless layer 2 packet (including the upper layer payload) in a PPP/PPPoE packet. The TAP device 306 forwards the PPP/PPPoE packet to the BE device 307 over the pre-established PPP/PPPoE connection. FIG. 6 shows a representation of a PPP/PPPoE protocol message 600 sent by the TAP device 306 to the BE device 307. The PPP/PPPoE protocol message 600 includes the wireless layer 2 packet (including the upper layer payload) encapsulated in a PPP/PPPoE packet. The TAP device 306 transmits the PPP/PPPoE protocol message 600 to the BE device 307 over the pre-established PPP/PPPoE connection.

FIG. 7 shows sample TAP device logic 700 for processing a wireless protocol message received from the TE device 102. Beginning at block 702, the logic receives a wireless protocol message from the TE device 102 including an upper layer payload encapsulated in a wireless layer 2 packet, in block 704. The logic extracts the wireless layer 2 packet including the upper layer payload from the wireless protocol message, in block 706. The logic encapsulates the wireless layer 2 packet including the upper layer payload in a PPP/PPPoE packet to form a PPP/PPPoE protocol message, in block 708, and forwards the PPP/PPPoE protocol message to the BE device 307 over the pre-established PPP/PPPoE communication connection, in block 710. The logic 700 terminates in block 799.

When the BE device 307 receives the PPP/PPPoE protocol message 600 from the TAP device 306, the BE device 307 decapsulates the wireless layer 2 packet (including the upper layer payload) from the PPP/PPPoE packet, and processes the wireless layer 2 packet and the upper layer payload. This processing typically involves, among other things, processing the wireless communication protocol layers of the wireless layer 2 packet and the upper layer payload as a termination point of the wireless communication protocol, and forwarding transport and application layer information from the upper layer payload to the host computer 108.

FIG. 8 shows sample BE device logic 800 for processing a PPP/PPPoE protocol message received from the TAP device 306. Beginning at block 802, the logic receives the PPP/PPPoE protocol message from the TAP device 306, in block 804. The logic decapsulates the wireless layer 2 packet including the upper layer payload from the PPP/PPPoE protocol message, in block 806. The logic processes the wireless layer 2 packet and the upper layer payload, in block 808. The logic 800 terminates in block 899.

Conversely, the host computer 108 communicates with the TE device 102 by sending transport and application layer information to the BE device

307. The BE device 307 forms a wireless layer 2 packet including an upper layer payload for sending the transport and application layer information to the TE device 102. The BE device 307 forms a PPP/PPPoE protocol message by encapsulating the wireless layer 2 packet (including the upper layer  
5 payload) in a PPP/PPPoE packet, as shown in FIG. 6, and sends the PPP/PPPoE protocol message to the TAP device 306 over the pre-established PPP/PPPoE connection. It should be noted that the BE device 307 is typically coupled to multiple TAP devices, and therefore the BE device 307 sends the PPP/PPPoE protocol message to the appropriate TAP device based upon  
10 addressing information provided by the host computer 108.

FIG. 9 shows sample BE device logic 900 for processing transport and application layer information received from the host computer 108.

Beginning at block 902, the logic receives transport and application layer  
15 information from the host computer 108, in block 904. The logic forms a wireless layer 2 packet including an upper layer payload based upon the transport and application layer information, in block 906. The logic then encapsulates the wireless layer 2 packet including the upper layer payload in a PPP/PPPoE packet to form a PPP/PPPoE protocol message, in block 908.  
20 The logic forwards the PPP/PPPoE protocol message to the TAP device 306 over the pre-established PPP/PPPoE communication connection, in block 910. The logic 900 terminates in block 999.

When the TAP device 306 receives the PPP/PPPoE protocol message  
25 600 from the BE device 307, the TAP device decapsulates the wireless layer 2 packet (including the upper layer payload) from the PPP/PPPoE packet, and sends a wireless protocol message to the TE device 102 using the wireless layer 1 protocol. As shown in FIG. 5, the wireless protocol message 500 includes the wireless layer 2 packet (including the upper layer payload) from  
30 the PPP/PPPoE packet. It should be noted that the TAP device 306 may be in communication with multiple TE devices, and therefore the TAP device 306 sends the wireless protocol message 500 to the appropriate TE device 102

based upon addressing information provided by the BE device 307 (e.g., in the wireless layer 2 packet).

FIG. 10 shows sample TAP device logic 1000 for processing the  
5 PPP/PPPoE protocol message received from the BE device 307. Beginning at  
block 1002, the logic receives the PPP/PPPoE protocol message from the BE  
device 307, in block 1004. The logic decapsulates the wireless layer 2 packet  
including the upper layer payload from the PPP/PPPoE packet, in block 1006.  
The logic sends a wireless protocol message to the TE device 102 including the  
10 wireless layer 2 packet with upper layer payload using the wireless layer 1  
protocol, in block 1008. The logic 1000 terminates in block 1099.

It should be noted that, in the embodiments described above, there is  
typically a peer PPP connection between the TE device 102 and the BE device  
15 307 as specified by the Bluetooth wireless communication protocol, and there  
is typically also a peer PPP/PPPoE connection between the TAP device 306  
and the BE device 307. These PPP-based connections are distinct. PPP-based  
protocol messages exchanged between the TE device 102 and the BE device  
307 pursuant to the Bluetooth wireless communication protocol are carried  
20 within PPP/PPPoE protocol messages exchanged between the TAP device  
306 and the BE device 307.

It should be noted that, in the event of a TAP device failure,  
particularly during communications between a TE device and the host  
25 computer, communications can be switched over to another TAP device. This  
would involve such things as identifying a new TAP device for the TE device  
(e.g., the next-closest TAP device to the TE device) and remapping  
communications from the failed (old) TAP device to the new TAP device by  
the BE device. Such a "hand-off" from the old TAP device to the new TAP  
30 device is described in the related application incorporated by reference above.



Likewise, communications can be switched over from one TAP device to another TAP device as the TE device moves away from the one TAP device and closer to the other TAP device, as described in the related application incorporated by reference above.

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It should be noted that the protocol stacks shown and described with reference to FIG. 2 and FIG. 4 are exemplary of the LAN Access Profile of the Bluetooth specification. However, the present invention can be applied to other Bluetooth profiles as well as to other communication protocols and profiles. Typically, embodiments implementing other Bluetooth profiles require appropriate changes to at least the upper protocol layers of the TE device 102 and the BE device 307.

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In the described embodiments, the TAP devices are coupled to the BE device over an Ethernet LAN and communicate with the BE device using PPP/PPPoE communication connections. However, the present invention is in no way limited by the way in which the TAP devices communicate with the BE device. The TAP devices can communicate with the BE device using any of a variety of communication technologies and protocols.

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In the described embodiments, the wireless communication protocol is the Bluetooth wireless communication protocol. However, the present invention is in no way limited to the Bluetooth wireless communication protocol or to any particular wireless communication protocol. Various aspects of the present invention can be applied to other wireless communication protocols, including modifications and derivations of the Bluetooth wireless communication protocol.

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It should be noted that the term "packet" is used herein to describe a communication message that may be used by a communication device (e.g., created, transmitted, received, stored, or processed by the communication device) or conveyed by a communication medium, and should not be

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construed to limit the present invention to any particular communication message type, communication message format, or communication protocol. Thus, a communication message may include, without limitation, a frame, packet, datagram, user datagram, cell, or other type of communication message.

It should also be noted that the logic flow diagrams are used herein to demonstrate various aspects of the invention, and should not be construed to limit the present invention to any particular logic flow or logic implementation. The described logic may be partitioned into different logic blocks (e.g., programs, modules, functions, or subroutines) without changing the overall results or otherwise departing from the true scope of the invention. Often times, logic elements may be added, modified, omitted, performed in a different order, or implemented using different logic constructs (e.g., logic gates, looping primitives, conditional logic, and other logic constructs) without changing the overall results or otherwise departing from the true scope of the invention.

The present invention may be embodied in many different forms, including, but in no way limited to, computer program logic for use with a processor (e.g., a microprocessor, microcontroller, digital signal processor, or general purpose computer), programmable logic for use with a programmable logic device (e.g., a Field Programmable Gate Array (FPGA) or other PLD), discrete components, integrated circuitry (e.g., an Application Specific Integrated Circuit (ASIC)), or any other means including any combination thereof. In a typical embodiment of the present invention, predominantly all of the TAP device logic and BE device logic is implemented as a set of computer program instructions that is converted into a computer executable form, stored as such in a computer readable medium, and executed by a microprocessor within the TAP device 306 and BE device 307, respectively, under the control of an operating system.

Computer program logic implementing all or part of the functionality previously described herein may be embodied in various forms, including, but in no way limited to, a source code form, a computer executable form, and various intermediate forms (*e.g.*, forms generated by an assembler, compiler, linker, or locator). Source code may include a series of computer program instructions implemented in any of various programming languages (*e.g.*, an object code, an assembly language, or a high-level language such as Fortran, C, C++, JAVA, or HTML) for use with various operating systems or operating environments. The source code may define and use various data structures and communication messages. The source code may be in a computer executable form (*e.g.*, via an interpreter), or the source code may be converted (*e.g.*, via a translator, assembler, or compiler) into a computer executable form.

The computer program may be fixed in any form (*e.g.*, source code form, computer executable form, or an intermediate form) either permanently or transitorily in a tangible storage medium, such as a semiconductor memory device (*e.g.*, a RAM, ROM, PROM, EEPROM, or Flash-Programmable RAM), a magnetic memory device (*e.g.*, a diskette or fixed disk), an optical memory device (*e.g.*, a CD-ROM), a PC card (*e.g.*, PCMCIA card), or other memory device. The computer program may be fixed in any form in a signal that is transmittable to a computer using any of various communication technologies, including, but in no way limited to, analog technologies, digital technologies, optical technologies, wireless technologies (*e.g.*, Bluetooth), networking technologies, and internetworking technologies. The computer program may be distributed in any form as a removable storage medium with accompanying printed or electronic documentation (*e.g.*, shrink wrapped software), preloaded with a computer system (*e.g.*, on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the communication system (*e.g.*, the Internet or World Wide Web).

Hardware logic (including programmable logic for use with a programmable logic device) implementing all or part of the functionality

previously described herein may be designed using traditional manual methods, or may be designed, captured, simulated, or documented electronically using various tools, such as Computer Aided Design (CAD), a hardware description language (*e.g.*, VHDL or AHDL), or a PLD  
5 programming language (*e.g.*, PALASM, ABEL, or CUPL).

Programmable logic may be fixed either permanently or transitorily in a tangible storage medium, such as a semiconductor memory device (*e.g.*, a RAM, ROM, PROM, EEPROM, or Flash-Programmable RAM), a magnetic  
10 memory device (*e.g.*, a diskette or fixed disk), an optical memory device (*e.g.*, a CD-ROM), or other memory device. The programmable logic may be fixed in a signal that is transmittable to a computer using any of various communication technologies, including, but in no way limited to, analog technologies, digital technologies, optical technologies, wireless technologies  
15 (*e.g.*, Bluetooth), networking technologies, and internetworking technologies. The programmable logic may be distributed as a removable storage medium with accompanying printed or electronic documentation (*e.g.*, shrink wrapped software), preloaded with a computer system (*e.g.*, on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the  
20 communication system (*e.g.*, the Internet or World Wide Web).

The present invention may be embodied in other specific forms without departing from the true scope of the invention. The described embodiments are to be considered in all respects only as illustrative and not  
25 restrictive.